PROCEEDINGS *of the* FIFTH BERKELEY SYMPOSIUM ON MATHEMATICAL STATISTICS AND PROBABILITY

Held at the Statistical Laboratory
University of California
June 21–July 18, 1965
and
December 27, 1965–January 7, 1966

with the support of
University of California
National Science Foundation
National Institutes of Health
Air Force Office of Scientific Research
Army Research Office
Office of Naval Research

VOLUME V

WEATHER MODIFICATION

EDITED BY LUCIEN M. LE CAM
AND JERZY NEYMAN

UNIVERSITY OF CALIFORNIA PRESS
BERKELEY AND LOS ANGELES
1967

TRACKING SILVER IODIDE NUCLEI UNDER OROGRAPHIC INFLUENCE

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During the past twenty years, since Vincent Schaefer and Bernart Vonnegut demonstrated that clouds could be modified by the introduction of artificial freezing nuclei, there have been massive assumptions and impressive voids in our knowledge of plume patterns associated with silver iodide dispensed from aircraft and groundbased sources. These assumptions have probably contributed more to the erratic project results and apparent failures of some field programs than any other single source of difficulty. If a single program is dependent upon the arrival in time and distribution in space of a given material, the need to determine these variables seems elementary and of first order importance.

For the past eleven years there has been an operating cloud seeding program on the Kings River watershed in the southern portion of California's Sierra range. The program includes the use of 30 silver iodide ground generators and supplementary seeding from aircraft using both silver iodide and dry ice. Until 1962, this program made no effort to determine the dimensions of plumes from either ground or aircraft sources. As in other programs, it had been assumed that if the material were dispensed somewhere upwind from a given target area it would eventually arrive at the right place and at the proper time.

In the early winter of 1962 a program was initiated to establish the areal distribution of silver iodide downwind from ground generator sites and certain aircraft seeding flights. While the program was not designed as a tight quantitative investigation, it was felt that it would not be too difficult to establish the general boundaries of the plumes as well as give some feeling about the normal background count of natural freezing nuclei under various meteorological conditions.

The equipment chosen for this work was the Portable Cold Box manufactured some years ago by Meteorology Research, Inc., Altadena, California. Essentially this unit is composed of a one liter chamber immersed in a bath of alcohol. Solid carbon dioxide serves as the coolant for the isopropyl alcohol which is circulated around the cold chamber by pressure from the CO_2. The temperature in the cold chamber is controlled by the rate of alcohol circulation throughout the system. A collimated light source, one centimeter thick, directed into the cold chamber provides illumination. A simple optical system mounted above the cold chamber provides appropriate viewing. The optical system contains a grid network which allows the viewer to examine about 30 cubic centimeters of volume in the

illuminated portion of the cold chamber. Fittings on the top of the unit provide a means for introducing air samples and moisture.

Since 1960, cloud seeding efforts in the southern Sierra area have supported the use of a Piper Apache aircraft. This twin engine ship is equipped with superchargers and complete deicing facilities. Numerous navigational aids provide the final equipment necessary for accurate positioning of the aircraft. An air intake is mounted on the nose of the aircraft and connected to latex tubing which runs to the cold box in the aircraft's cabin. The Piper Apache has served as an excellent platform for the Portable Cold Box and has provided outstanding service to the plume tracking program during the past three years.

If the detection of freezing nuclei is desired during any portion of the flight, an air sample is introduced into the cold chamber and appropriate moisture is added from an external nebulizer. The resultant supercooled cloud in the cold chamber is then viewed through the optical system and any ice crystals formed begin to scintillate in the light beam and may be counted behind the grid network. The temperature in the cold chamber is usually preset before the flight but may be changed during flight operations if a few minutes temperature stabilization period is available. A period of two minutes is considered adequate for the total operation of introducing the air sample and actually counting the scintillating ice crystals which grow in the cold box.

The range of the Portable Cold Box in terms of minimum and maximum concentrations of freezing nuclei in any given air sample is about 10^4 to 10^7 nuclei per cubic meter. Anything substantially less than 10^4 nuclei per cubic meter is not enough to assure the viewer that a single ice crystal will pass through the illuminated volume of the cold chamber. Concentrations greater than 10^7 nuclei per cubic meter produce such a shower of ice crystals in the illuminated volume that it is difficult to count the total numbers visually.

These limitations to the tight quantitative analysis of freezing nuclei in any given volume of air do not seriously affect a tracking program designed to establish the general boundaries of a silver iodide plume. An experienced viewer can easily determine if he is "in" or "out" of the plume even though he might not be able to apply a *precise* quantitative figure either to the natural background count or to the point of highest concentration within the plume.

During the period from November 1962 through April 1964, a total of thirty nine aircraft flights were made for the purpose of identifying freezing nuclei over the southern portion of the Sierra range in California (see figure 1). Eleven of these flights were made when no seeding efforts were reported in the area. With the exception of one flight in this series to identify natural freezing nuclei, counts were below the minimum end of the cold box range.

Twelve of the total flights were made when silver iodide was dispersed from the seeding aircraft. In all of these flights, if the check points indicated values greater than 10^4 nuclei per cubic meter, the aircraft was assumed to be in the plume. Values quickly dropped to substantially less than 10^4 nuclei per cubic meter when the aircraft moved beyond the plume into uncontaminated air.

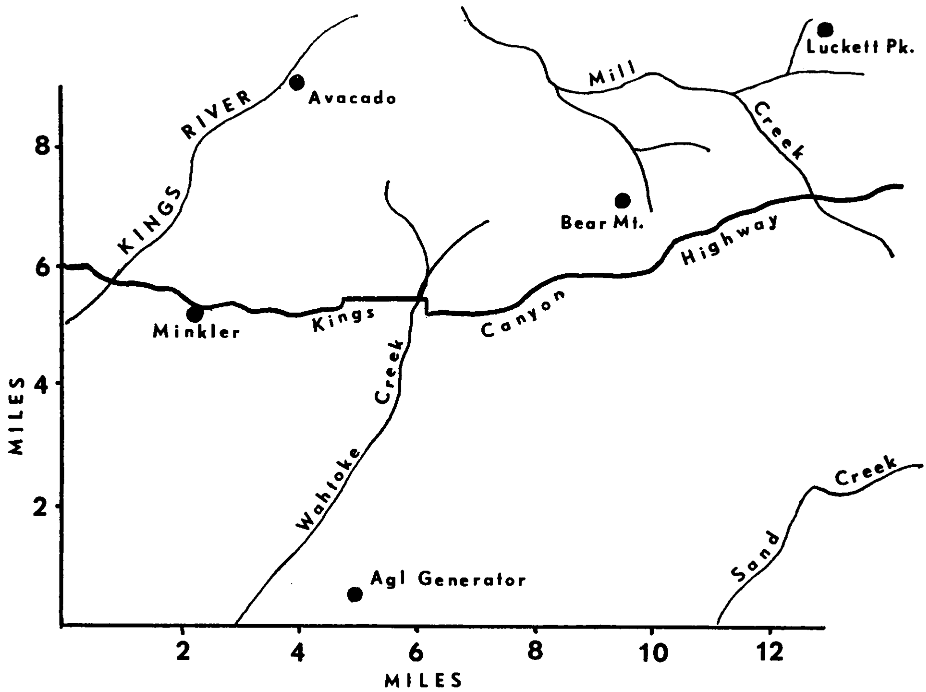

FIGURE 1

Map of study area.

Sixteen of the total flights were initiated when silver iodide ground generators were in operation. Criteria for assuming contact with the plume was the same as in the case of aircraft dispersal of silver iodide. Total sample points during each flight ranged from a minimum of 9 to a maximum of 29.

In addition to the thirty nine flights made for the purpose of identifying freezing nuclei plumes above ground level, there were twenty two ground sorties made for purposes of establishing a particular ground pattern to plumes coming from ground generator sites. Again, it was assumed that contact with the plume had been made when the nuclei count rose above 10^4 per cubic meter. In the various study areas, the roads were plentiful and passable enough to allow reasonable sampling downwind from the generator sites. Total sample points during each ground sortie ranged from 12 to 32.

The temperature of the cold chamber during each of the sixty one tests was set in the range between $-15°$ C and $-20°$ C.

Profile and plan views plotted from five cases of ground generator dispersal and aerial tracking are shown in figures 2 to 6. The scale and positioning is the same as the map in figure 1, so that it may be overlaid to identify any position. In each of these figures the location of the ground generator and direction of the

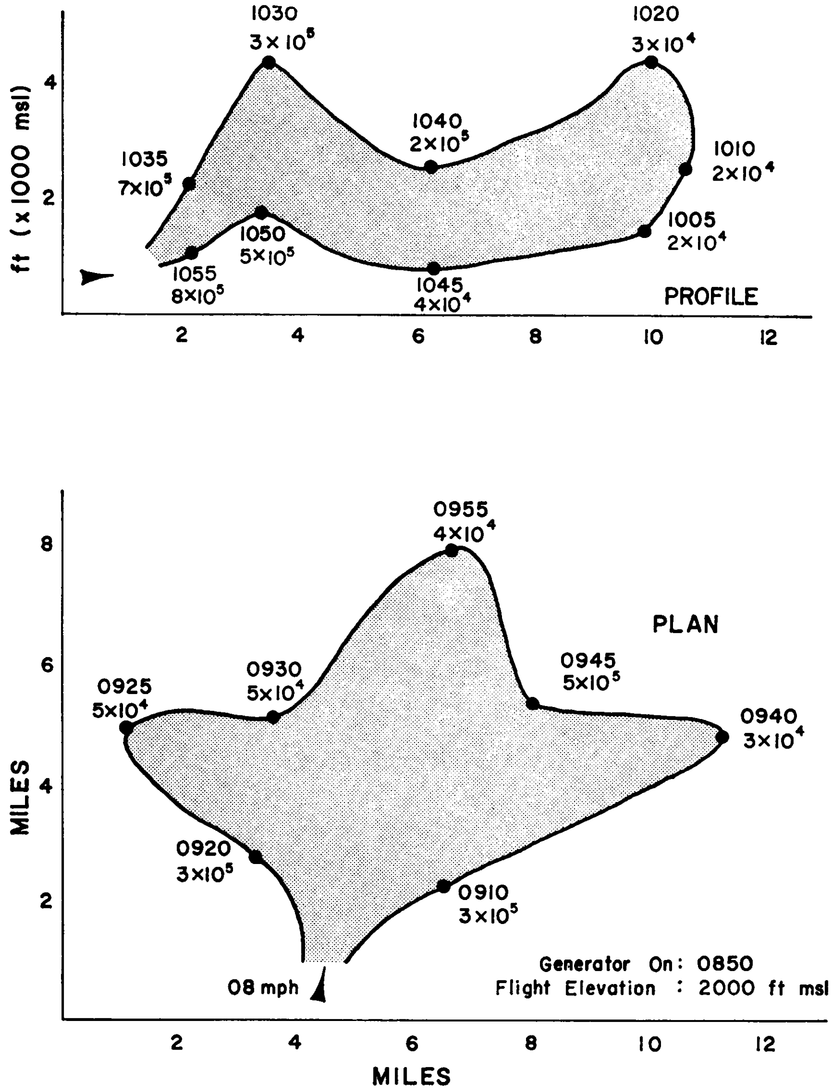

FIGURE 2

Silver iodide plumes as tracked by the aircraft downwind from the ground generator site indicated by arrow near origin of each plume. Wind velocity is shown at generator site. Direction is given by arrow.

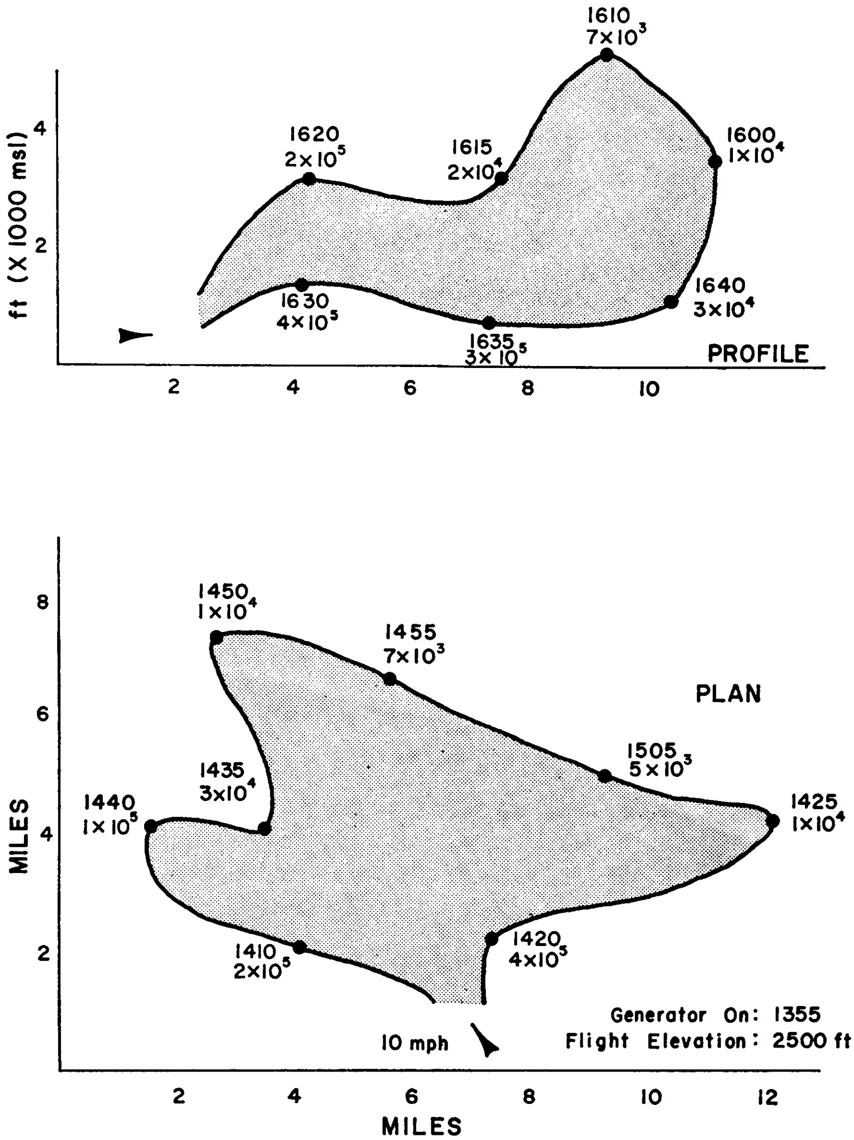

FIGURE 3

wind flow at the site are shown by the arrows. The average wind velocity, time of initial generator ignition, and aircraft elevation during sampling are also shown. The location of the sample points where they met the plume, the actual nuclei count, and the real time of each sample have been added to the figures. To avoid confusion, the actual flight path of the aircraft is not shown but it may be easily estimated by following the time sequence shown on each drawing. All

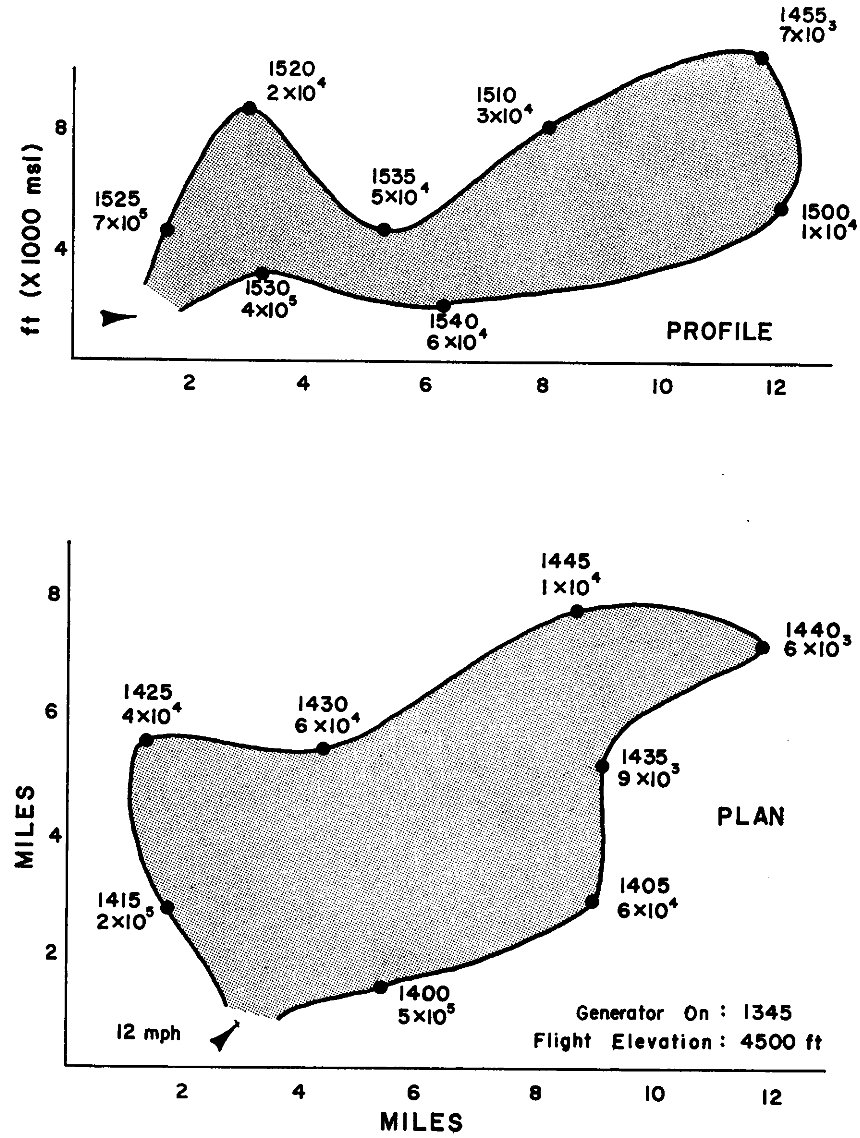

FIGURE 4

the plumes shown in the figures are from data taken on five separate days, but resulted from silver iodide dispensed from the same generator location. No silver iodide was dispensed from other locations during these particular tracking efforts.

Subsequent to the sample program during thirty nine flights and twenty two ground sorties plus the data plotting necessary to establish freezing nuclei plume

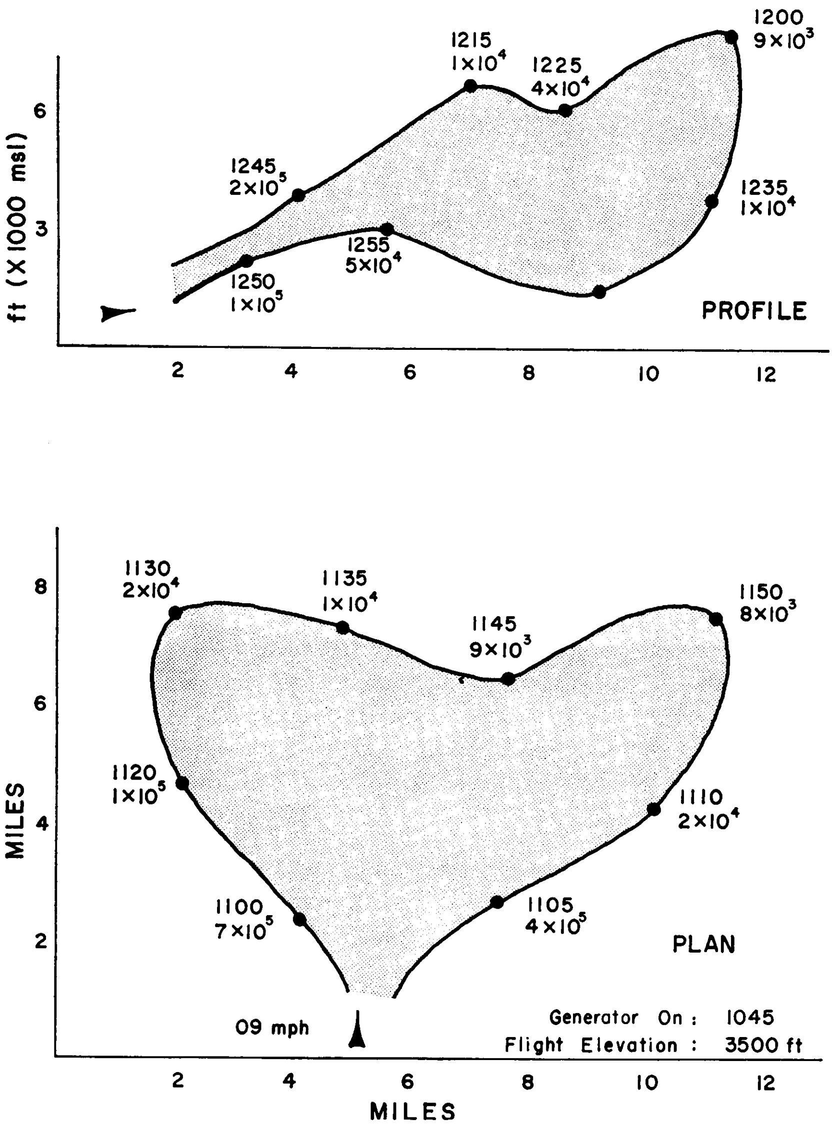

FIGURE 5

patterns, the following items appear significant.

(1) Silver iodide freezing nuclei plumes as dispersed from aircraft and ground generator sources are reasonably easy to track with the Portable Cold Box.

(2) Freezing nuclei plumes rarely conform to specific patterns and their dimensions in both time and space are unpredictable even when a given meteorological condition is similar to a previous experience.

(3) It would be risky to make assumptions about the distribution of silver

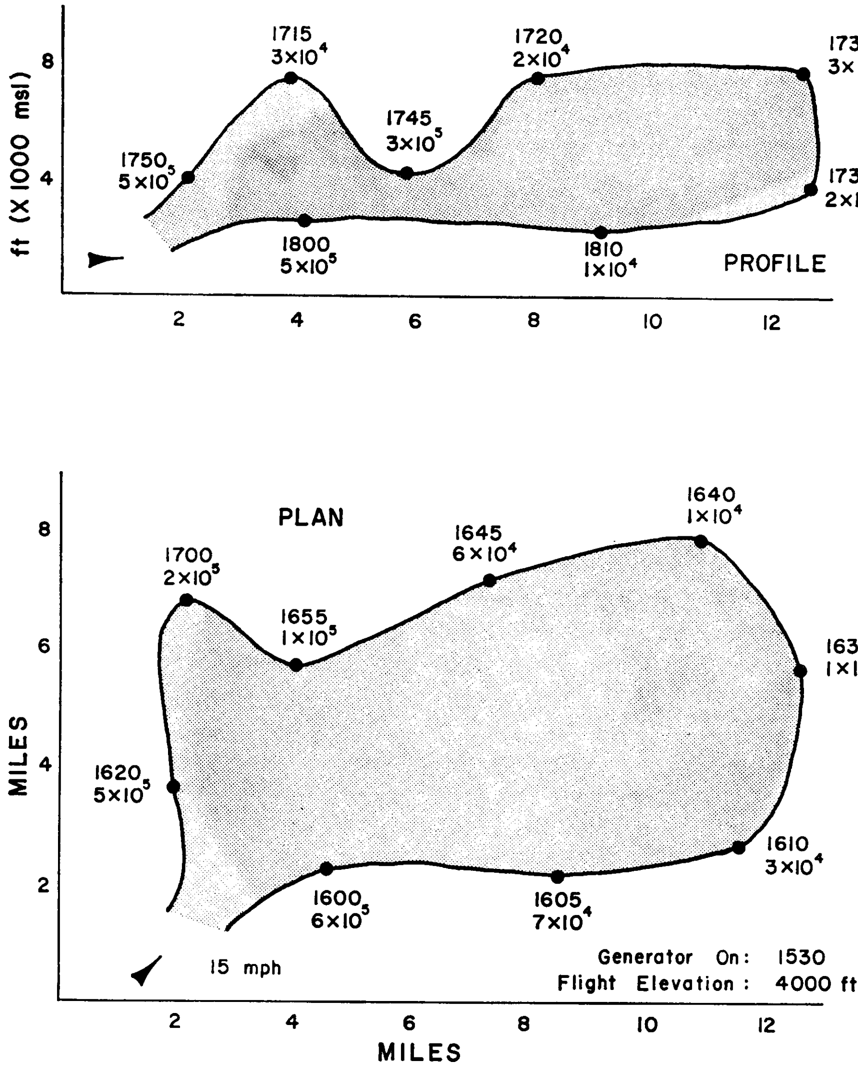

FIGURE 6

iodide plumes if a field program were dependent upon the material reaching a given area at a particular time and in a certain concentration.

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